

# Recent Spin Physics Results from HERMES and Plans for RHIC

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for the  **hermes** -Collaboration

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## *Outline:*

- *Inclusive measurements*
- *Transversity*
- *Future prospects*

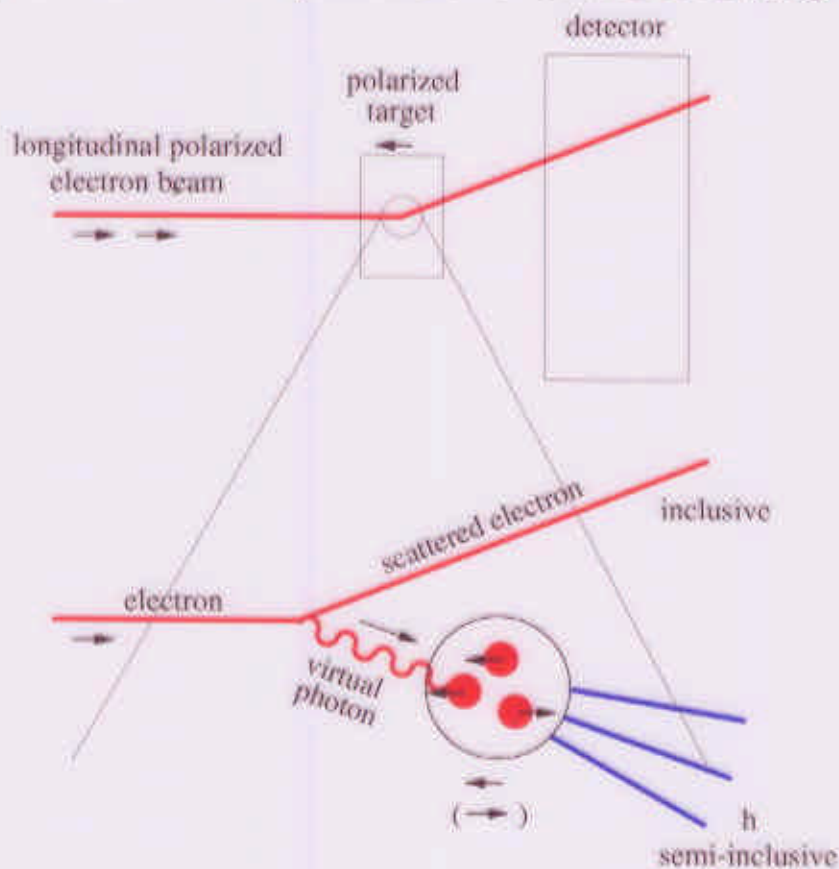
## Motivation

$$s_z^N = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_G$$

$$\begin{aligned}\Delta\Sigma &= \Delta u + \Delta d + \Delta s \\ &= \Delta u_v + \Delta d_v + \\ &\quad \Delta u_s + \Delta \bar{u}_s + \Delta d_s + \Delta \bar{d}_s + \Delta s + \Delta \bar{s}\end{aligned}$$

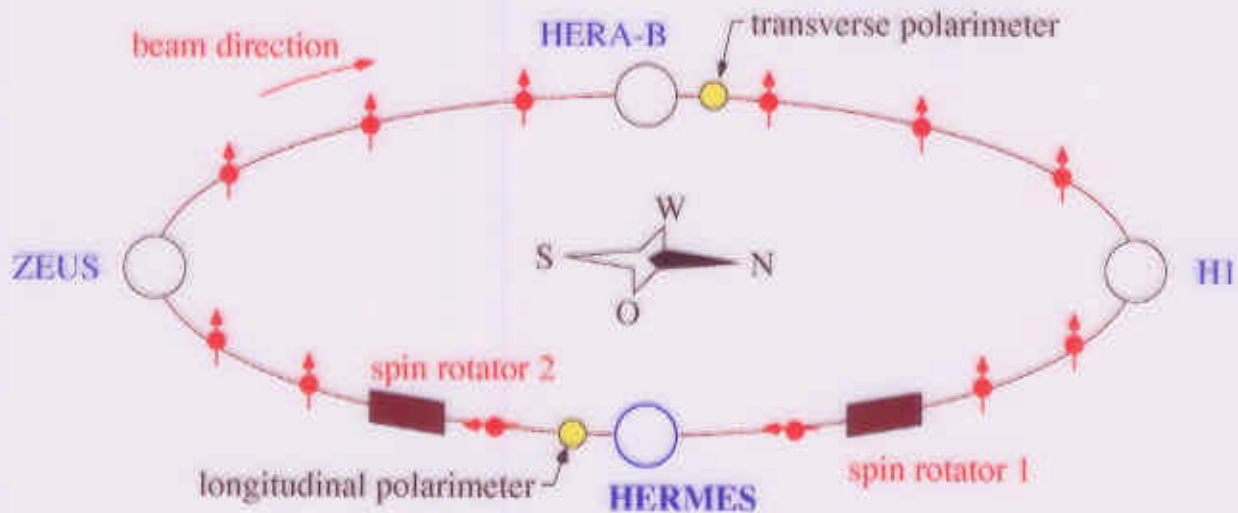
Measurement :  $\Delta\Sigma \approx 0.2 - 0.3$

Spin dependent deep inelastic eN scattering



## The HERMES-Experiment

Beam:  $P_B \approx 50 - 60\%$

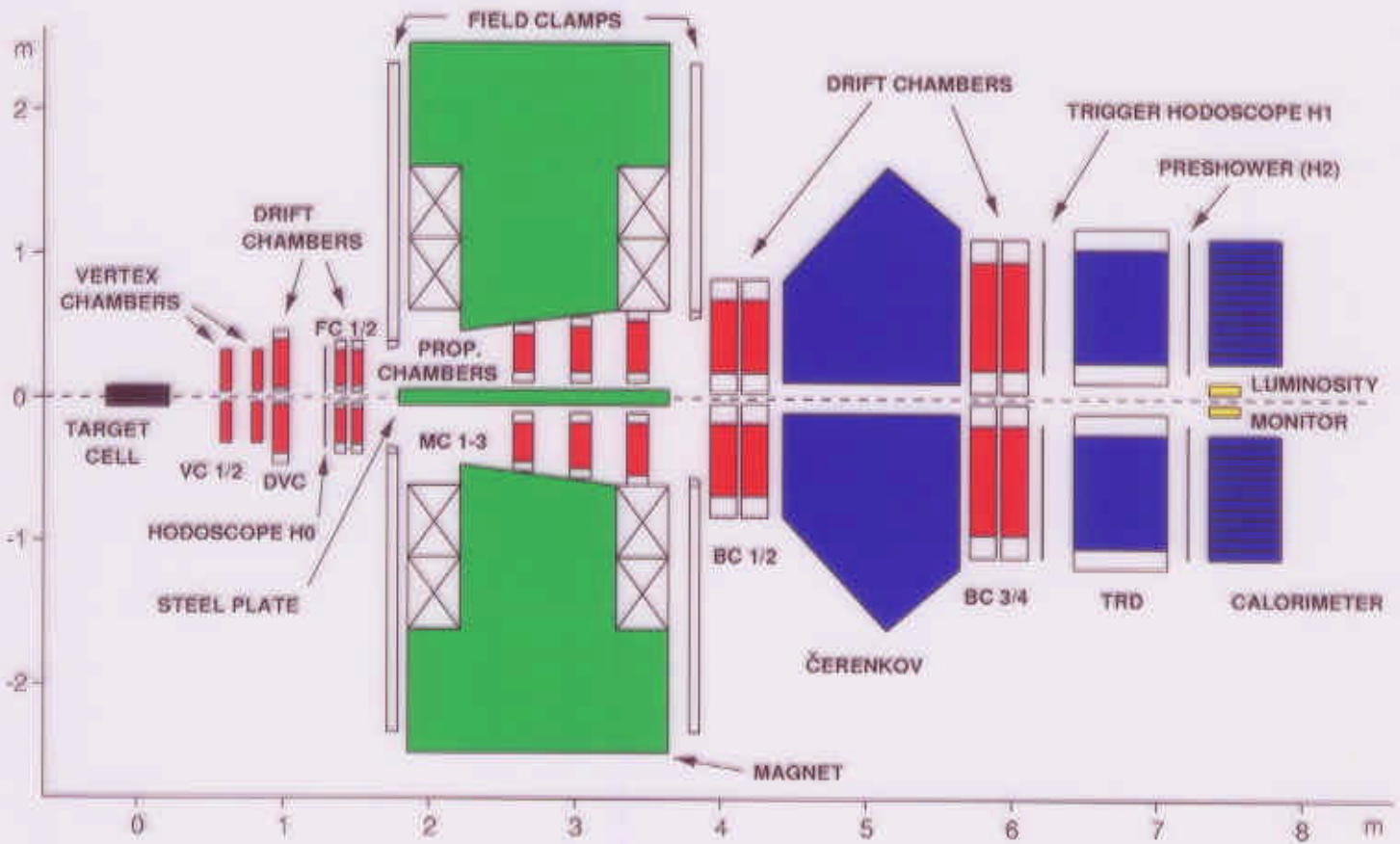


Target: Internal polarized gas target  
(Hydrogen, Deuterium,  $^3\text{He}$ )

$$P_T(\vec{H}, \vec{D}) \approx 90\%$$

$$P_T(\vec{^3\text{He}}) \approx 50\%$$

# Spectrometer:



(NIM A417 (1998) 230)

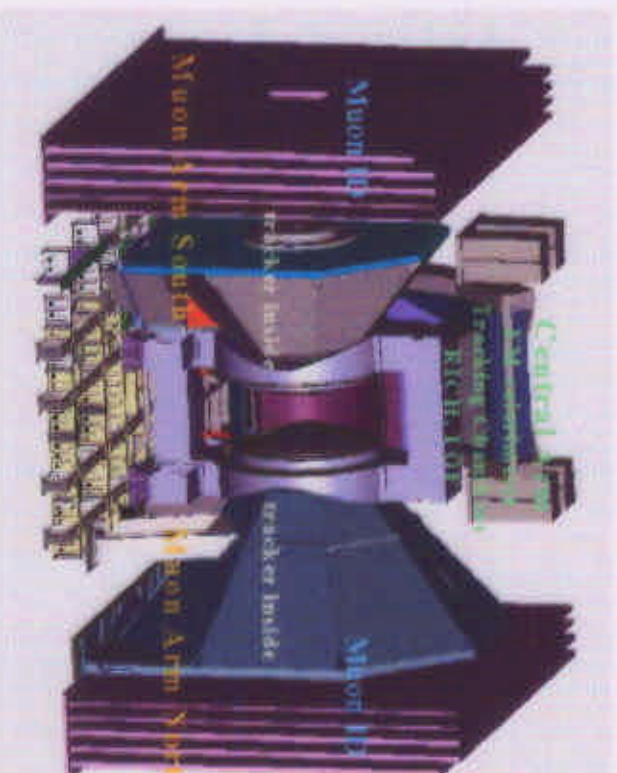
# RHIC Spin Project

## RIKEN BNL Collaboration

- PHENIX Muon Arm with LANL and Polarized Beam Acceleration with BNL Spin Rotators for PHENIX and STAR will be fabricated and installed under this collaboration

$$50 \leq \sqrt{s} \leq 500 \text{ GeV}; P_B \approx 70\% \quad L \approx 2.0 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1} \text{ @ } 500 \text{ GeV}$$

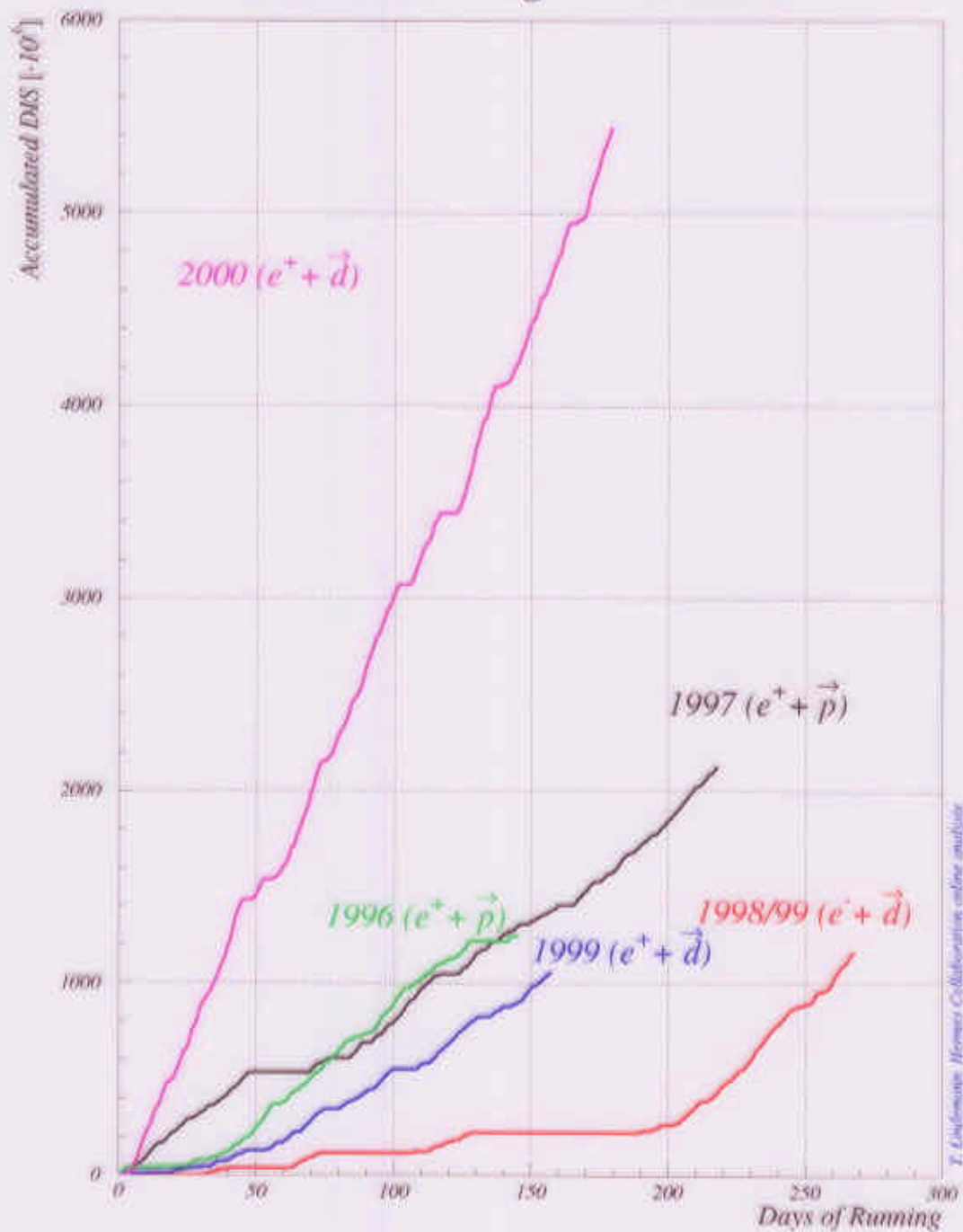
Siberian snake to maintain polarization  
Spin Rotators to obtain given polarization



## HERMES-Running:

1995:	1996:	1997:	1998:	1999:	2000:
$\vec{^3\text{He}}$	$\vec{\text{H}}$	$\vec{\text{H}}$	$\vec{\text{D}}$	$\vec{\text{D}}$	$\vec{\text{D}}$

## Hermes Running 1996-2000

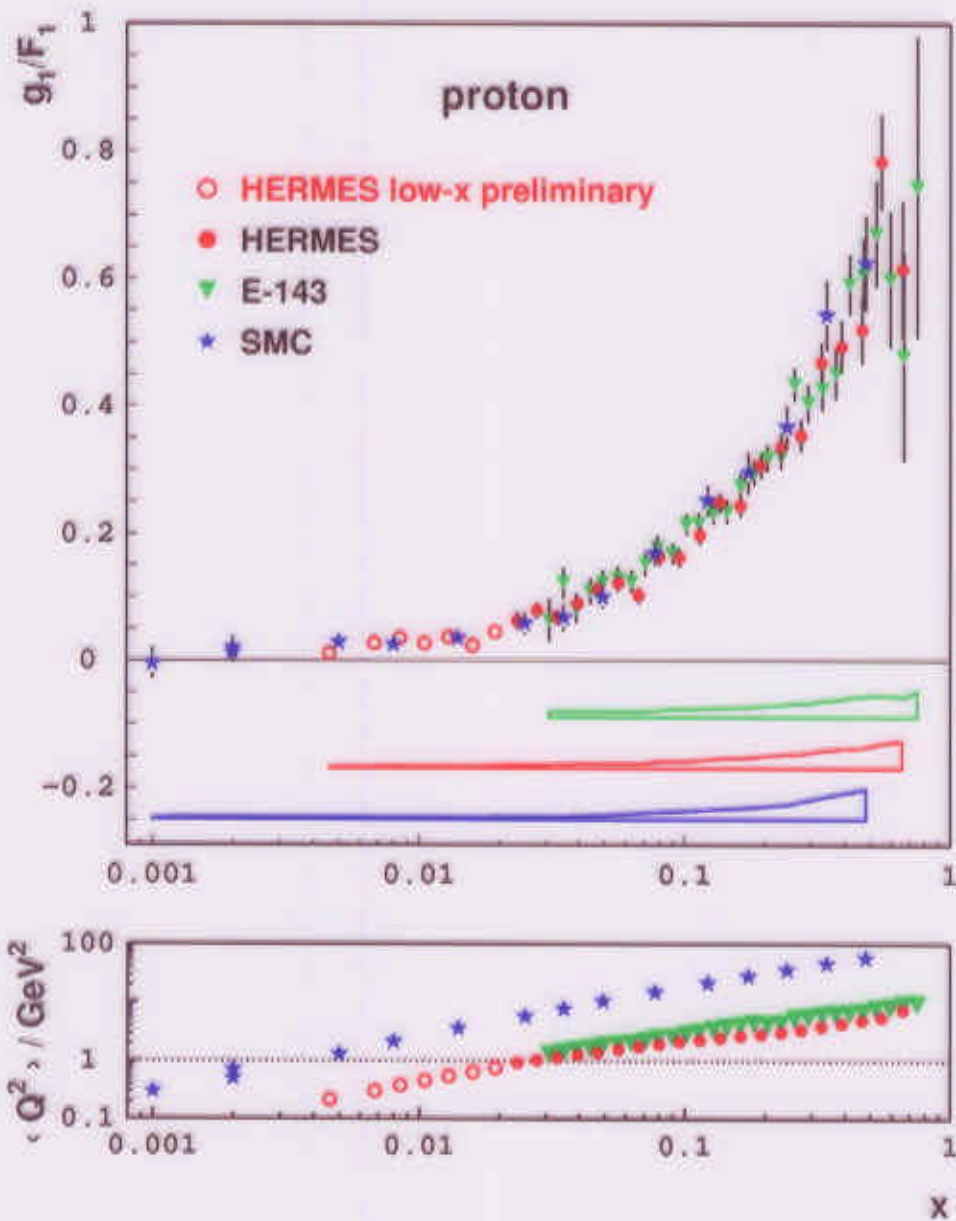


## Inclusive Results

The Asymmetry  $\frac{g_1^p}{F_1^p}$  of the Proton

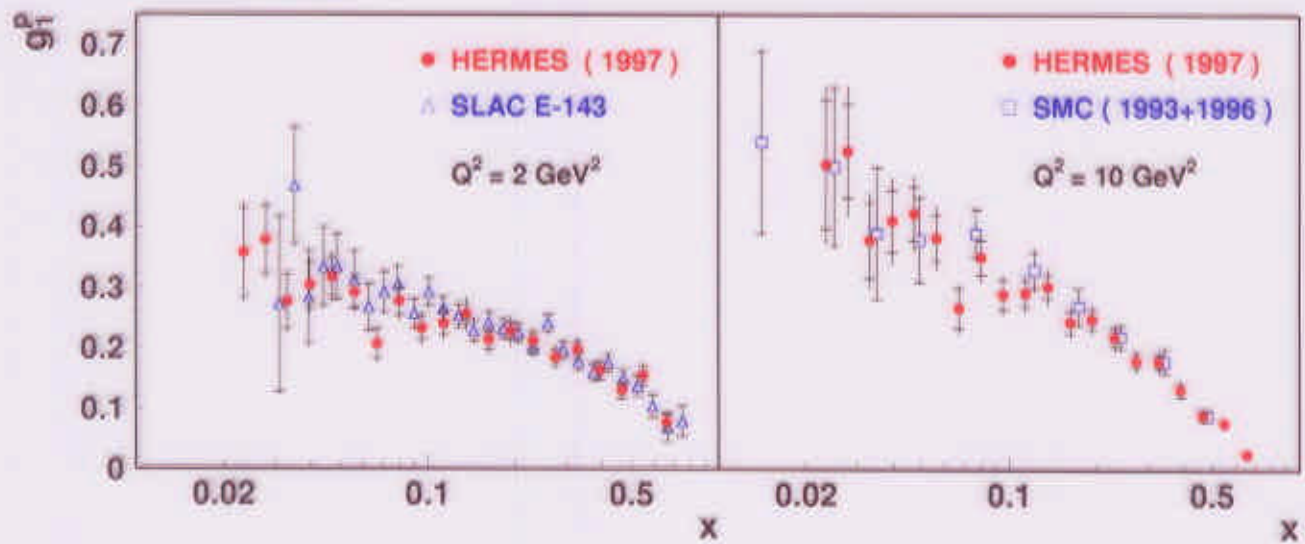
$$A_{||} = \frac{N_{\leftarrow}^{\rightarrow} - N_{\rightarrow}^{\rightarrow}}{N_{\leftarrow}^{\rightarrow} + N_{\rightarrow}^{\rightarrow}}, \quad \frac{g_1}{F_1} = \frac{1}{1+\gamma^2} \left( \frac{A_{||}}{D} - (\eta - \gamma) A_2 \right)$$

$$F_1(x) = \sum_f \frac{1}{2} e_f^2 q_f(x), \quad g_1(x) = \sum_f \frac{1}{2} e_f^2 \Delta q_f(x)$$



(Phys. Lett. B442 (1998) 484)

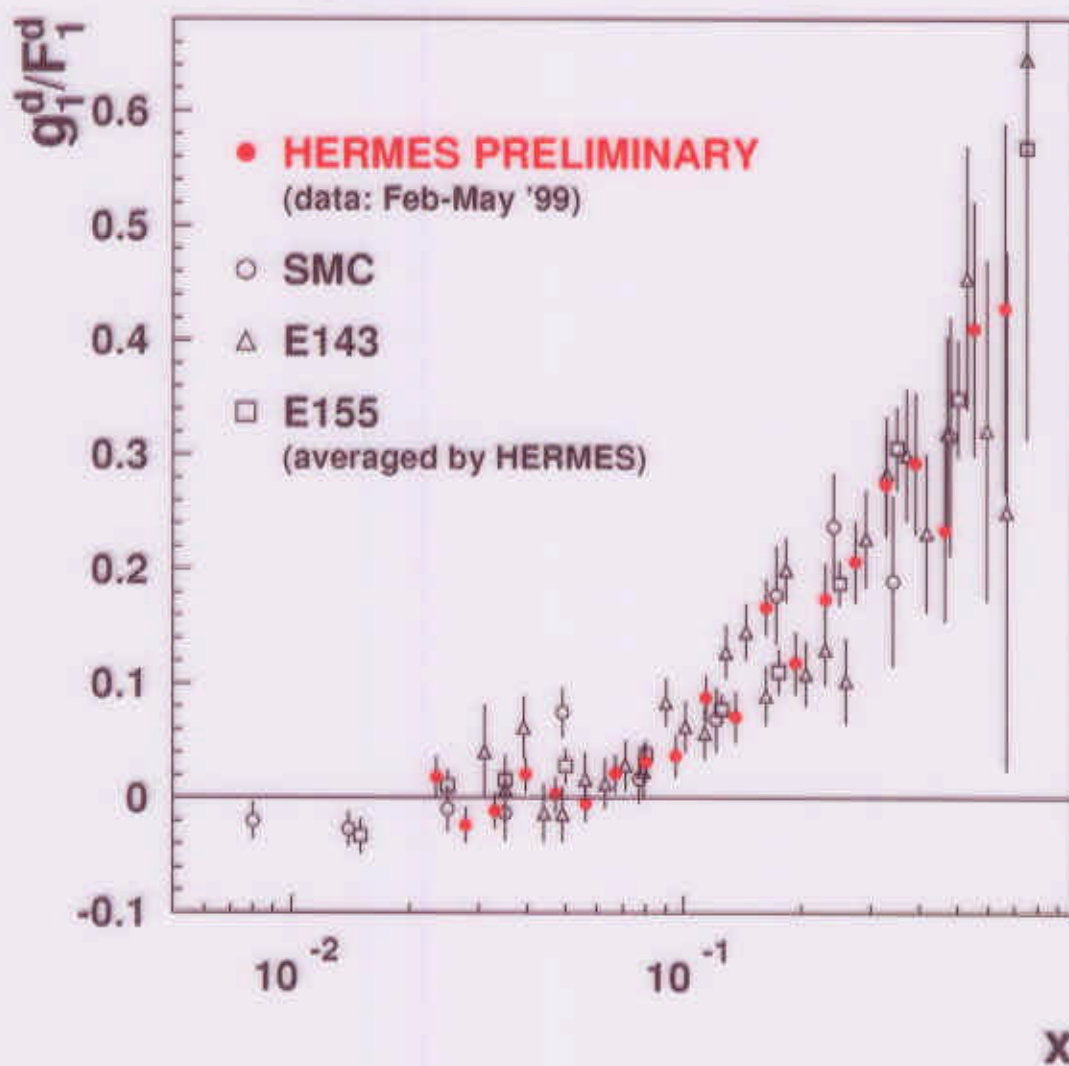
## Proton Spin Structure Function $g_1^p$



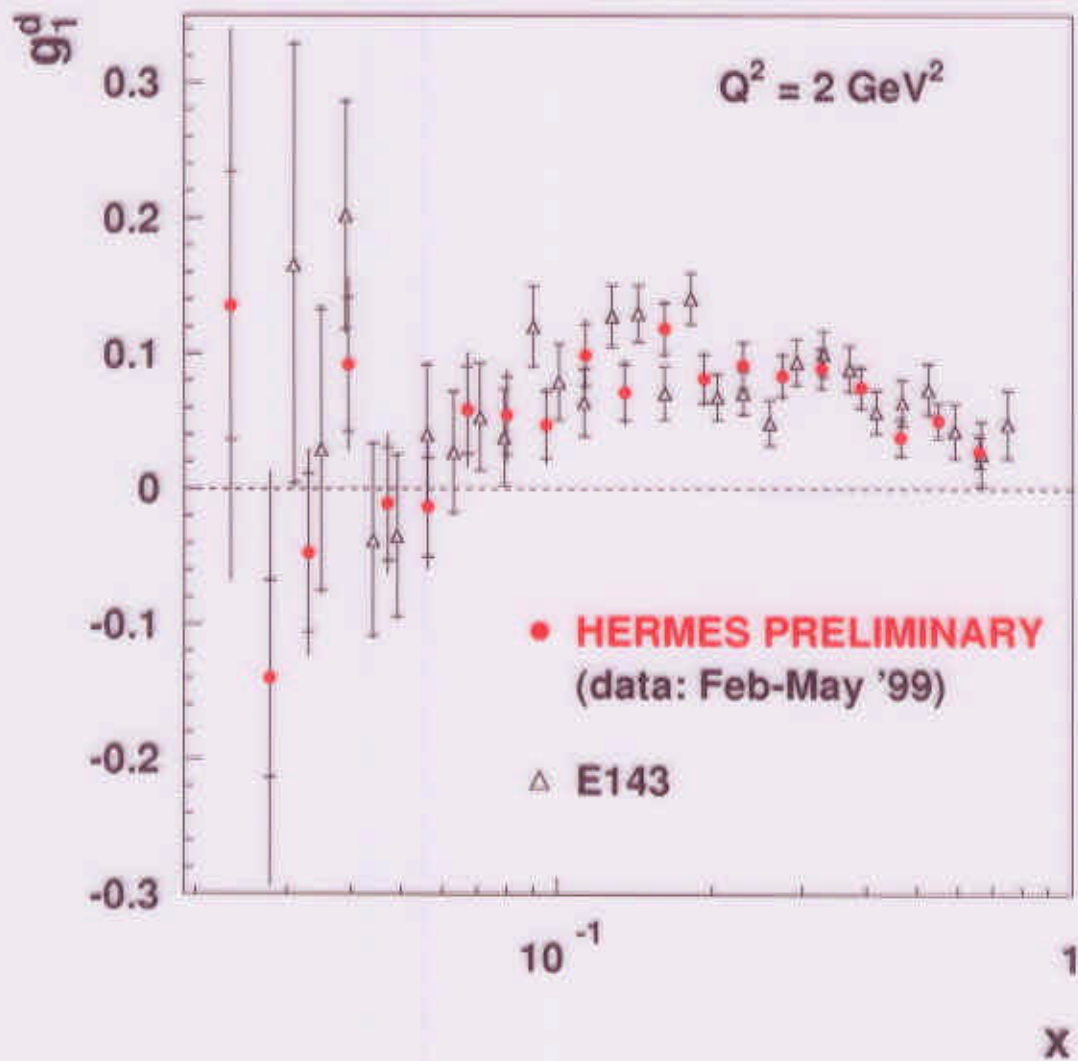
(Phys. Lett. B442 (1998) 484)



# The Asymmetry $\frac{g_1^d}{F_1^d}$ of the Deuteron



No. of events: 1 million  
 Final statistic:  $\approx 8$  million  
 Dilution factor:  $f=1$

Deuteron Spin Structure Function  $g_1^d$ 

## Transversity

3 Parton distribution functions at leading twist:

$$f_1 = \text{[Diagram: a circle with a black dot in the center]}$$

unpolarized quark in unpolarized nucleon

$$g_{1L} = \text{[Diagram: a circle with a black dot and a red arrow pointing right]} \text{ - } \text{[Diagram: a circle with a black dot and a red arrow pointing left]} \text{ - } \text{[Diagram: a circle with a black dot and a green arrow pointing right]}$$

longitudinally polarized quark in longitudinally polarized nucleon

$$h_1 = \text{[Diagram: a circle with a black dot, a red arrow pointing up, and a green arrow pointing up]} \text{ - } \text{[Diagram: a circle with a black dot, a red arrow pointing down, and a green arrow pointing up]}$$

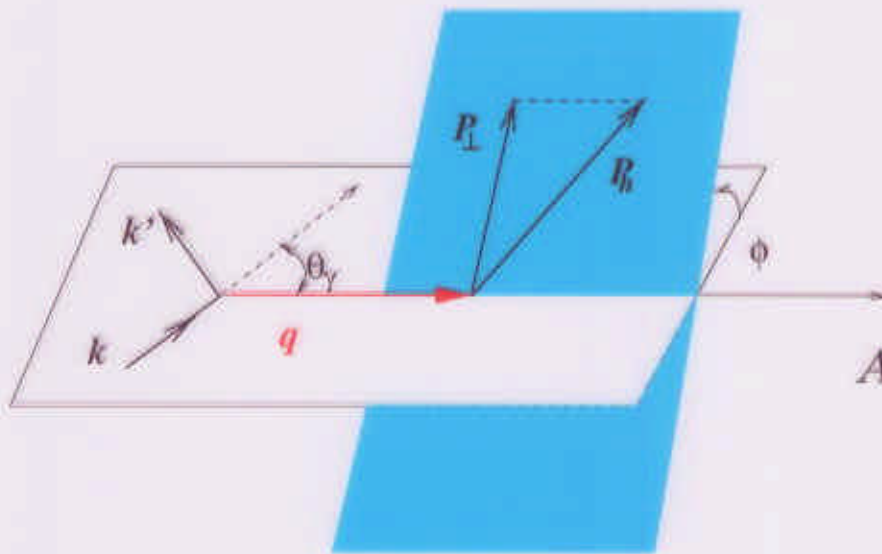
transversely polarized quark in transversely polarized nucleon

- predominantly valence quark object
- gluon polarization does not mix with quark polarization in  $h_1$



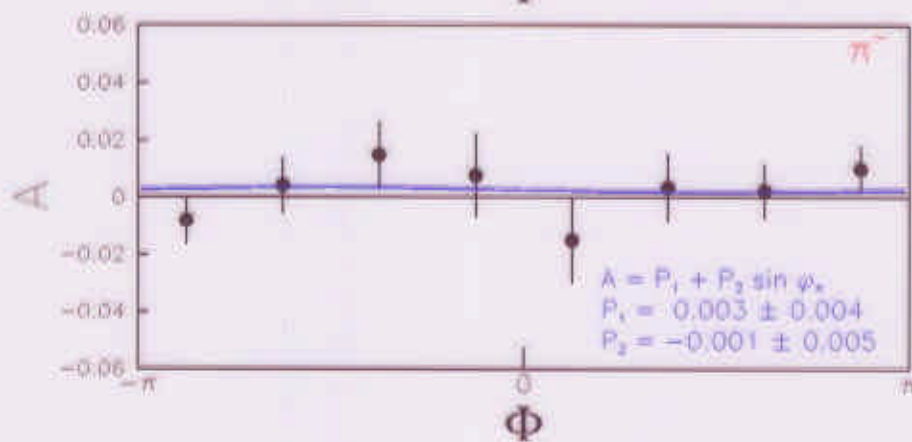
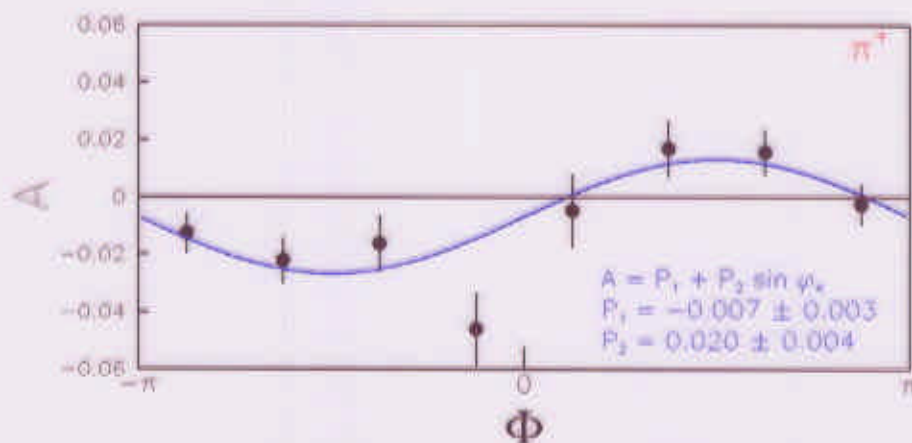
transverse quark polarization densities accessible via single spin azimuthal asymmetries

# Single Spin-Azimuthal Asymmetry



Longitudinal target polarization

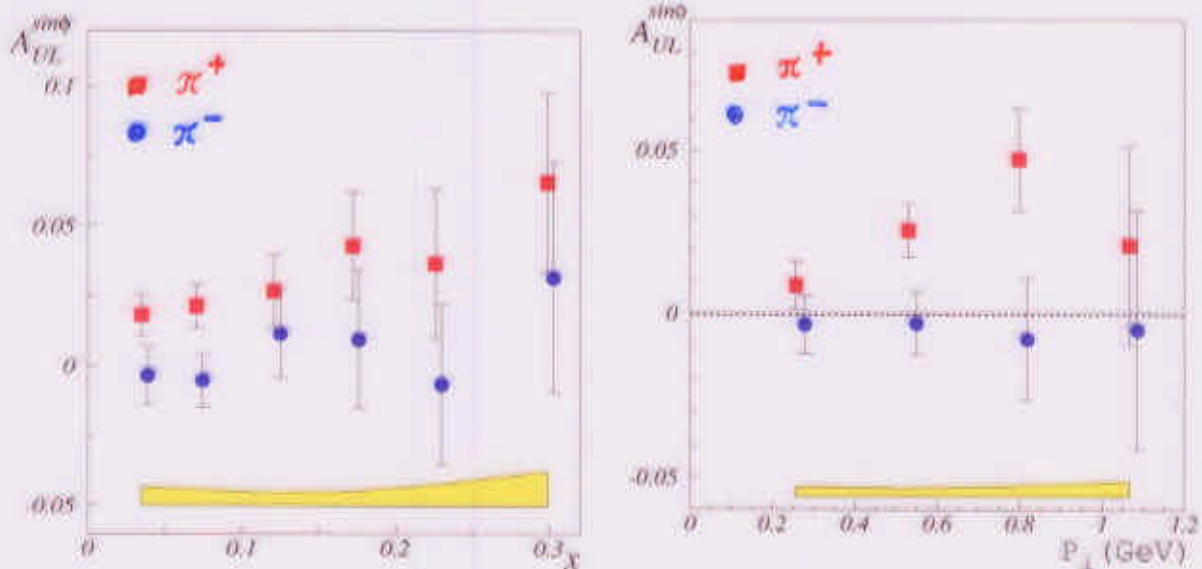
$$A_{UL}(\phi) = \frac{1}{\langle P \rangle} \cdot \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$



(Phys. Rev. Lett. 84 (2000) 4047)

## $A_{UL}^{\sin(\phi)}$ Behaviour

$A_{UL}^{\sin(\phi)} = \langle \sin(\phi) \rangle$  moment of longitudinal target asymmetry  
 $\rightarrow$  related to product of  $h_1(x)$  and  $H_1^\perp(z)$   
 ( $H_1^\perp(z) \equiv$  Collins Fragmentation Function)



(Phys. Rev. Lett. 84 (2000) 4047)

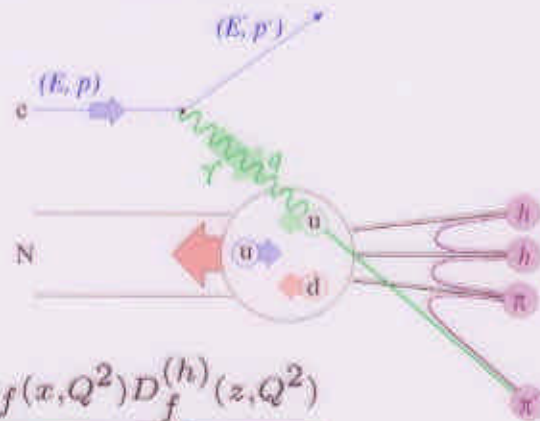
Original Predictions of Collins (Collins, Nucl. Phys. B396 (1993) 161)

- (?) Effect should be largest at  $x \gtrsim 0.3$
- (✓) Effect should be stronger for  $\pi^+$  than  $\pi^-$  (u-quark dominance)
- (✓) Effect should grow with  $p_T$  and peak at  $p_T \approx \text{few } 100 \text{ MeV} - 1 \text{ GeV}$

$\Rightarrow$  good prospects for future transversity program with transverse target polarization.

# Semi-inclusive Results and Projections

Semi-inclusive Asymmetry  $\frac{g_1^{(h)}}{F_1^{(h)}}$



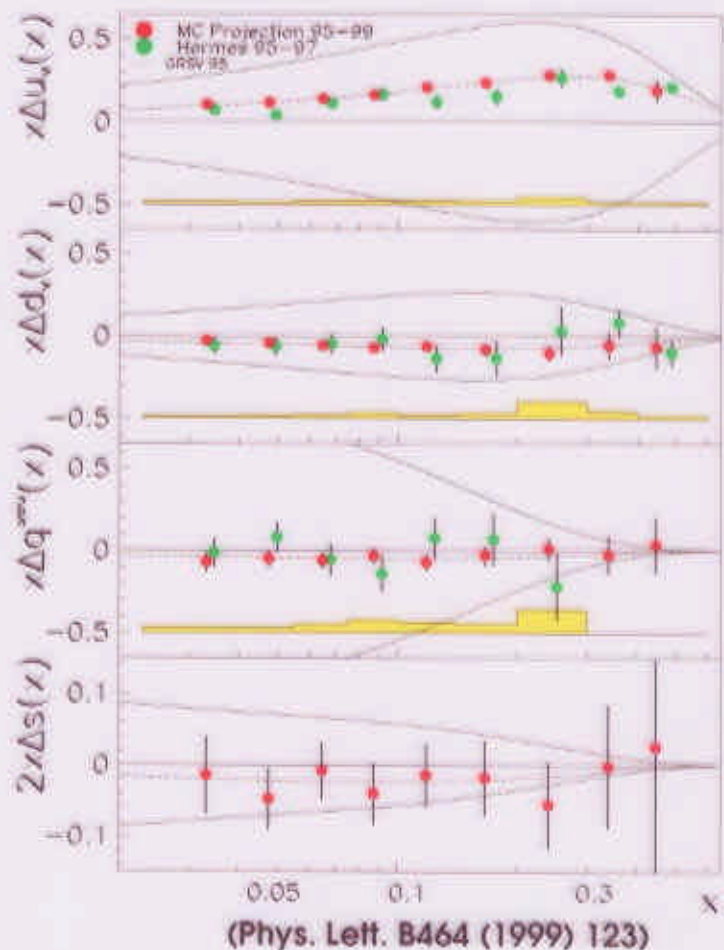
$$A_1^{(h)} \approx \frac{g_1^{(h)}(x, Q^2)}{F_1^{(h)}(x, Q^2)} = \frac{\int dz \sum_f e_f^2 \Delta q_f(x, Q^2) D_f^{(h)}(z, Q^2)}{\int dz \sum_f e_f^2 q_f(x, Q^2) D_f^{(h)}(z, Q^2)}$$

98-00: High quality  $\vec{D}$  data

- precise measurement of d-quark polarization

Installation of RICH

- direct measurement of sea polarization for different flavours

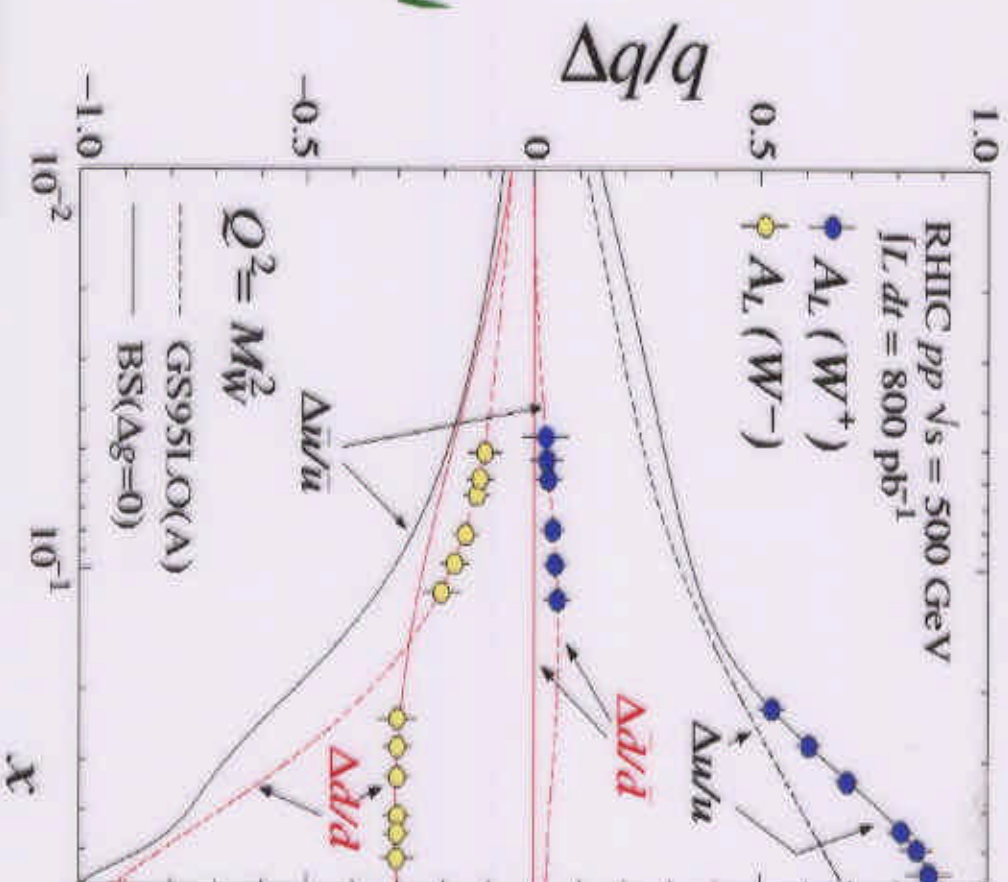


$$\Delta\Sigma = 0.30 \pm 0.04 \pm 0.09$$

Other contributions???  $\Rightarrow \Delta G$

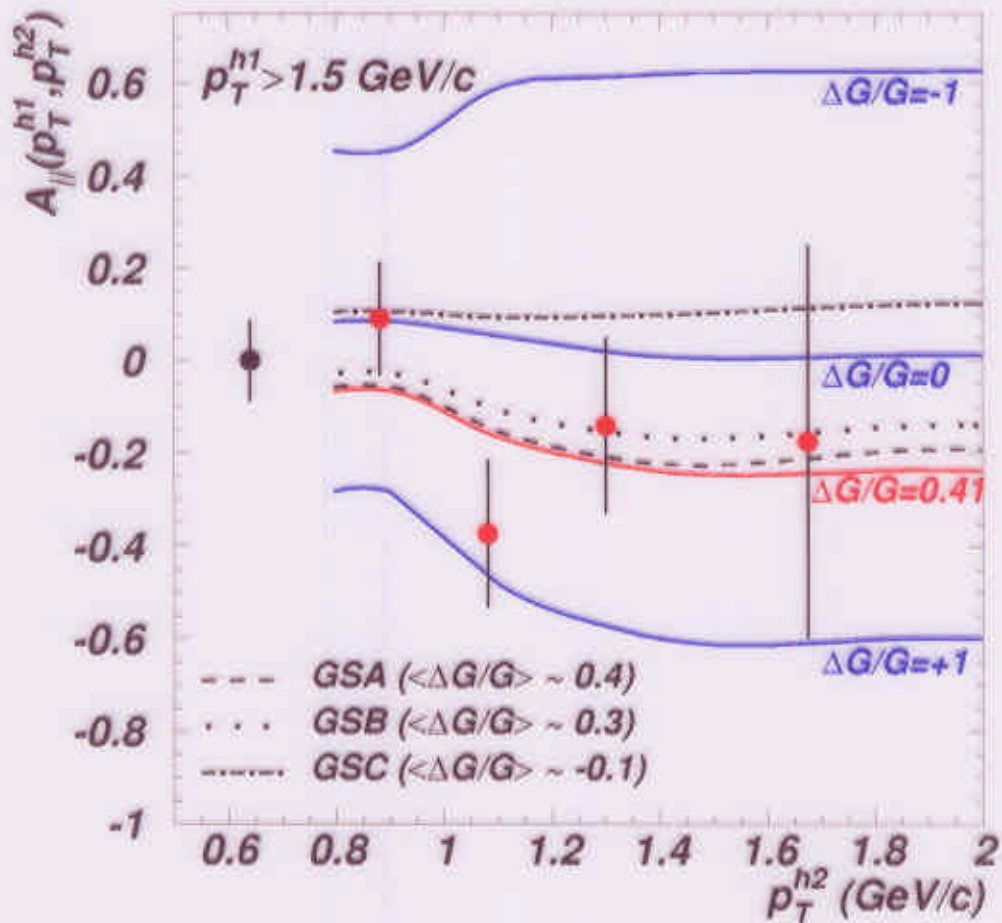
# W Production: Projected Error

- No assumption on sea polarization needed
- 500 GeV
- -800 pb<sup>-1</sup> (4 months w/ 40%)



## Gluon Polarization

Asymmetry of high  $p_T$  hadron pairs:



(Phys. Rev. Lett. 84 (2000) 2584)

$$\frac{\Delta G}{G} = 0.41 \pm 0.18(\text{stat.}) \pm 0.03(\text{exp.syst.})$$

$$\text{for: } \langle x_G \rangle = 0.17, \quad \langle p_T^2 \rangle = 2.1 \text{ GeV}^2/c^2$$

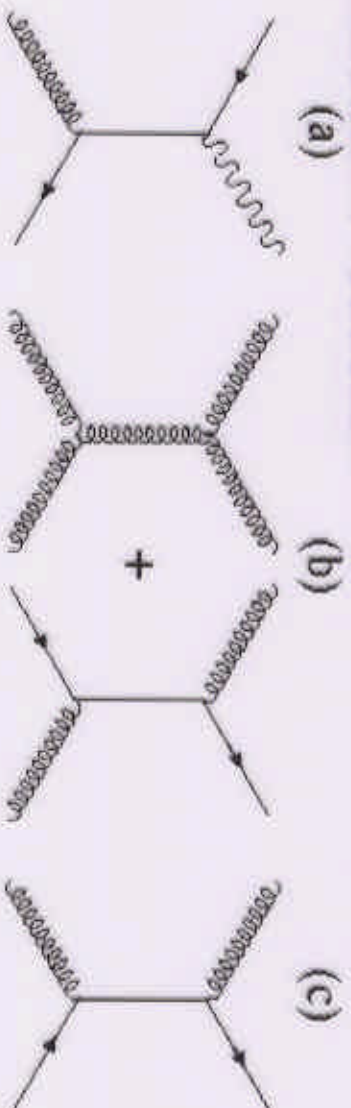
$$\int_{0.06}^{0.28} \frac{\Delta G}{G} G(x) dx \approx 0.6$$

Installation of RICH +  $\mu$ -wall in 1998  
 $\Rightarrow \Delta G$  via open charm

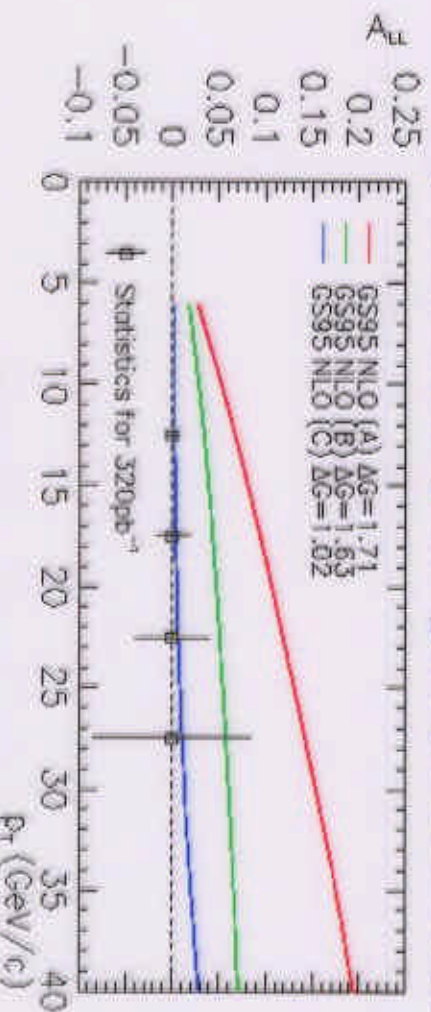


# Delta G Measurements

- RHIC Spin will measure  $\Delta g(x)$  in many channels
  - (a) Prompt Photon Production, (b) Jet Production, and (c) Open Charm/Bottom Production

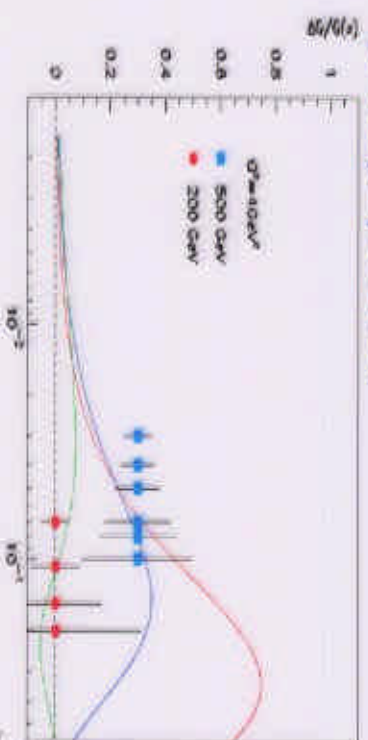


- Yuji Goto's study on "gold plated mode" = prompt photon



Prompt  $\gamma$  Asymmetry

Naohito Saito (RIKEN / RBRC)



## Further Highlights

### Polarized Physics Program

- Longitudinal Spin Transfer to  $\Lambda$   
(hep-ex/9911017)
- Spin Asymmetries in Diffractive Vector Meson Production
- 
- 

### Unpolarized Physics Program

- The Flavor Asymmetry of the Light Quark Sea  
(Phys. Rev. Lett. 81 (1998) 5519)
- Fragmentation Functions for light Quarks  $\rightarrow \pi, K, p, \Lambda$
- Diffractive Vector Meson Production (Coherence Length Effect, etc.)  
(Phys. Rev. Lett. 82 (1999) 3025, hep-ex/0002016, hep-ex/0004023)
- $F_2^N/He/F_2^D \rightarrow$  Nuclear Effects on  $\sigma_L/\sigma_T$   
(Phys. Lett. B 475 (2000) 386)
- 
- 
-

## HERMES Run 2: Transversity

2001 transversely polarized target

⇒ transversity,  $h_1$

Projections for statistical accuracy (Proton Target):

